# EARLY MORNING VARIATION OF IONIZATION AND THE TRUE HEIGHT OF REGION F OF THE IONOSPHERE*

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**ABSTRACT** Results of observations carried out at Calcutta (22°33' N) for a period of one year (1937-38) on the early morning variation of F-ionization are described. It is found that the average F-ionization, which decreases during the earlier part of the night, begins to increase after attaining a minimum. The hour, at which the increase begins, varies with the season. It occurs earliest in mid-winter and shifts towards the early morning hour with the approach of summer In mid-summer, there is no pre-sunrise increase of ionization This interesting result is explained as due to cooling of the layer as a whole It is obvious that the effect of contraction due to cooling is observable only if there be sufficient hours of darkness. The shifting of the hour of pre-sunrise increase towards the early morning hours and the absence of same in summer are thus easily explained. Further, it is found that the early morning minimum occurs *after sunrise at Region F* in all seasons.

In order to find out the hour of sunrise at Region F, its true height has been calculated from the observed (P' - *f*) curves Generally, the true height has been found to be about 80 km less than the observed equivalent height

Curves depicting the variation of the hour of sunrise with height, taking into account the effect of atmospheric refraction, have been drawn.

## I. INTRODUCTION

It is well known that the upper ionized Region F of the ionosphere is split up during daytime into two regions—$F_1$ (lower) and $F_2$ (upper). With the progress of night, $F_1$ gradually merges into $F_2$ and only one ionized upper region remains The Region $F_1$ in common with Region $E_1$ shows regular diurnal and seasonal variations of ionization. The Region $F_2$, however, does not do so. In fact, in many respects the variation of $F_2$-ionization with respect to the zenithal distance of the sun may be said to be erratic, and till now has received no satisfactory explanation. It is therefore necessary to make observations on the variation of $F_2$-ionization in relation to the incidence of solar radiation under as varied conditions as possible. An interesting and informative study is to find out how the $F_2$-ionization changes when the first rays of the rising sun strike it obliquely from below the horizon. Such a study has been made for the case of Region $E_1$ and an interesting fact has been discovered. It has been found [1] that the $E_1$-ionization begins to increase *not* when the early morning solar rays strike

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Region $E_1$ by grazing the surface of the earth *but* when they do so by grazing the top (at a height of about 35 km.) of the ozonosphere. It is important and interesting to enquire if some similar phenomena occur in the case of Region $F_2$.

Study of the correlation between the incidence of the rising sun's rays on Region F and the consequent change of ionization, if any, involves two subsidiary studies. It is necessary firstly to prepare a chart showing the hours of sunrise in different seasons at various heights above the earth's surface and secondly to determine the true height as opposed to the virtual height for every observation on Region F. The method of doing these and the results obtained are described in sections IV and V. In what follows we discuss the observed results on the assumption that these two data are known.

## II. METHOD OF OBSERVATION

The variation of F-ionization was studied by measuring the critical frequency at intervals of about 10 minutes. Since it was not possible to vary continuously the frequency of the exploring waves, the whole range of frequencies used was divided into steps 0·2 to 0·3 megacycle. The penetration frequency was determined by the usual method Each measurement took about 4 minutes.

During the months of July to December, 1937, weekly observations were, taken from about one hour before sunrise (at Region F) to about ground sunrise. For reasons given later, it was decided in January, 1938, to extend the period of observation from 2300 hours to ground sunrise on the next day.

## III. RESULTS AND DISCUSSION

In Figs. 1 to 8 the penetration frequencies have been plotted against time. The day-to-day variation of penetration frequency is irregular. The average variation for the month is therefore given and is shown by the thick continuous line. The hours of ground sunrise and the sunrise at the mean height of the F-layer are marked on the abscissa.

Inspite of the erratic nature of the variation of ionization, certain regular characteristic features of the average change of ionization during the early morning hours could be recognised. These are discussed below.

### *(a) Pre-sunrise Increase of Ionization*

Inspection of Figs. 1 to 3, 5 and 6 shows that there is in general an increase of ionization in the hours of darkness before the rising of the sun in the F-layer. It is also observed that the hour at which the ionization begins to increase recedes from the hour of sunrise (at F-layer) with the approach of the winter solstice.

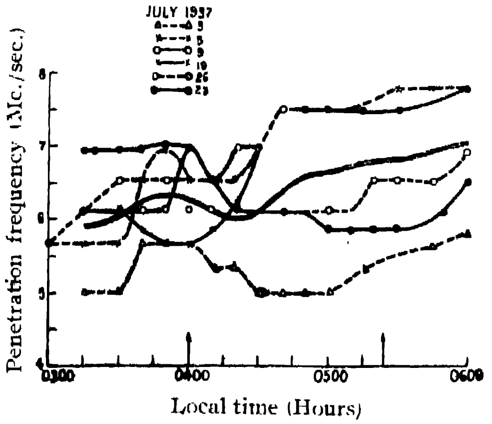



FIGURE 1

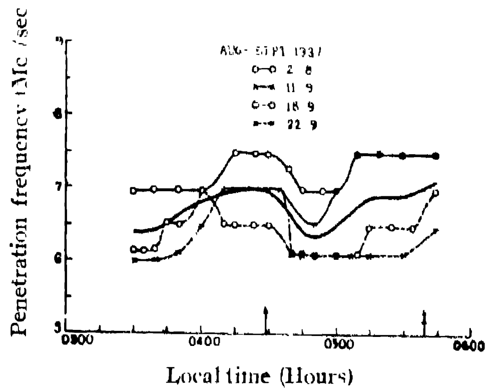
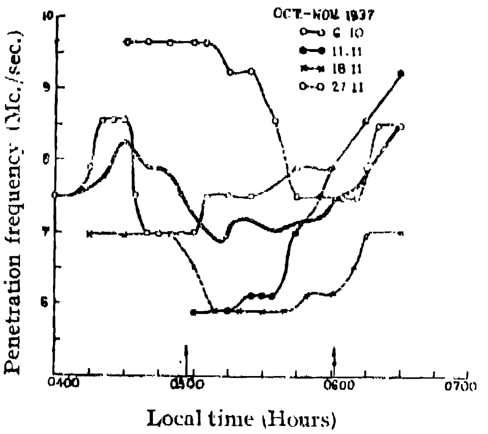



FIGURE 2

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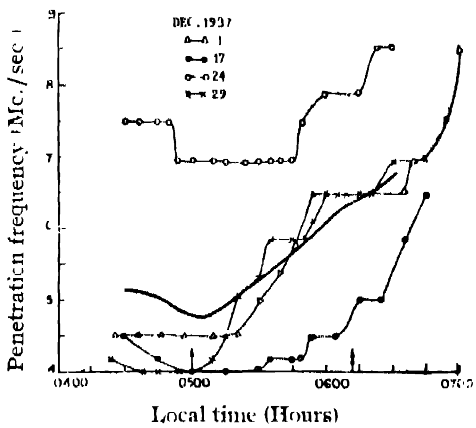


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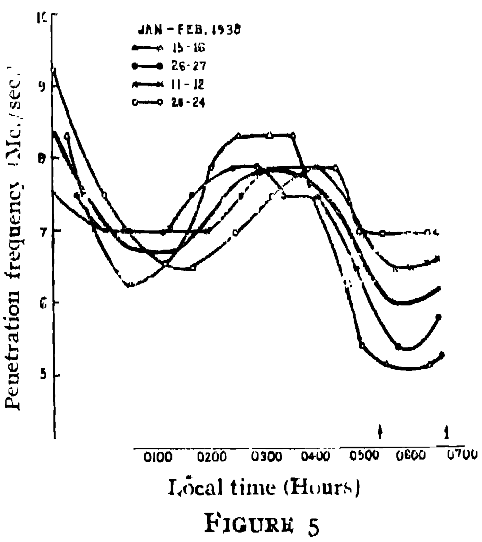


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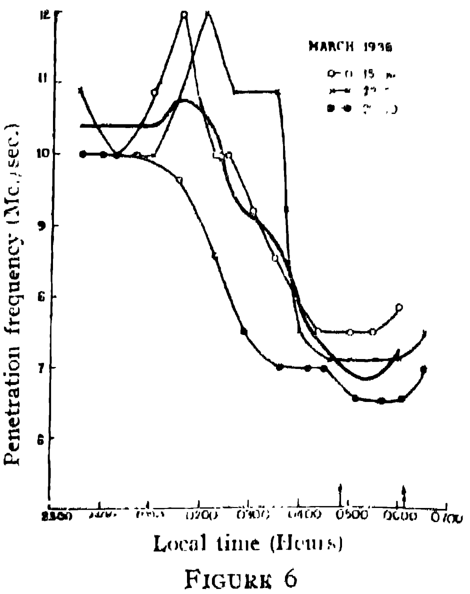


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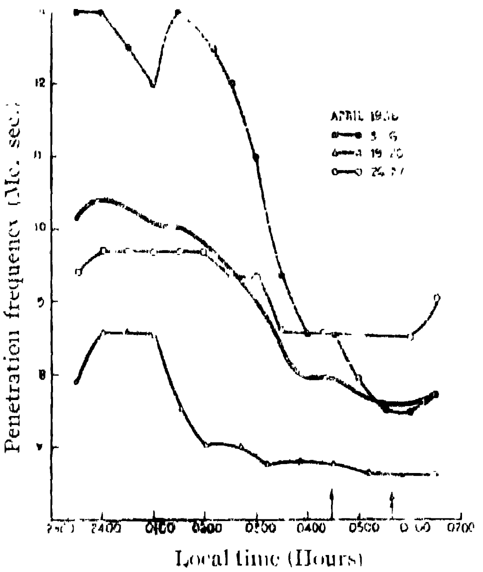


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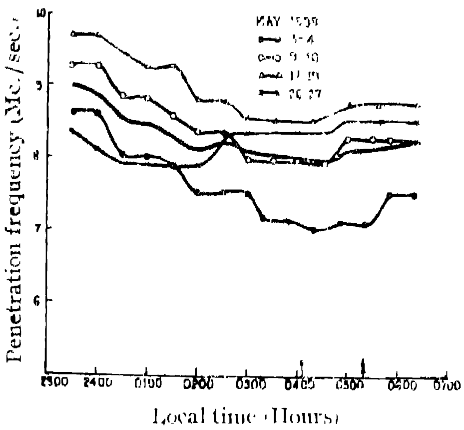



FIGURE 8

We note, for instance, that in the month of July, 1937, the hour of increase is 0320, that is, 40 minutes before the sunrise, whereas in January, 1938, the hour of increase is 0200, that is, 3 hrs. 20 mins. before the sunrise at F-layer.

*Note.*—The hour of increase of ionization could not be recorded in the month of December, 1937, as observations were not started early enough in the morning. The fact that we were unable to record the pre-sunrise increase of ionization by beginning our observations at the hour hitherto employed (about one hour before the sunrise in F-layer) led us to commence our observations in the following months at 2300 h.

The pre-sunrise increase of ionization has been observed by several workers amongst whom mention might be made of Gilliland,[2] Appleton and Naismith,[3] and Martyn and Pulley.[4] The last-named authors interpret this curious increase as due to the cooling of the layer as a whole and remark that this effect of cooling would be observable only in winter when sufficient hours of darkness are available. This hypothesis offers a simple explanation of the shifting of the hour of pre sunrise increase of ionization towards the earlier part of the night in winter. Since the sunset occurs earlier, the effect of contraction by cooling also occurs earlier. It should be noted further that with the approach of summer solstice, *i.e.*, in the months of April and May, 1938, no pre-sunrise increase is observed. This also can be explained if we remember that in these months the hours of darkness are small and hence before the contraction due to cooling is fully effective the sun's rays strike the layer and begin to warm it.

## (*b*) *Correlation with Sunrise*

As mentioned before, the ionization after increasing in the small hours of the morning begins to show a decrease. This phenomenon is very general and has been noticed by many investigators. One may explain this decrease as due to expansion by warming by the incidence of solar radiation as opposed to contraction by cooling during the dark hours. If this hypothesis is correct, then the hour of decrease must correspond to the hour of sunrise in the F-layer. Our observations indicate that some correspondence exists between the two only during the months of July to November (Figs. 1 to 3). But the evidence seems to be too weak to warrant any general conclusion.

One interesting point may be noted here. The ionization attains a minimum value after the sunrise at F-layer. This hour of minimum ionization is found to be farthest removed from the hour of sunrise in summer. With the approach of winter solstice, this hour tends to coincide with the hour of sunrise at F-layer. Thus the height of sunrise corresponding to the hour of early morning minimum of ionization is greater in winter than in summer. This has also been observed by Appleton and Naismith [3] in England and by Mathur [3] at Allahabad. This shifting of the hour of early morning minimum of ionization may be explained as follows :

In the early morning, after sunrise at Region F, the F-ionization density depends primarily upon two factors—(*i*) the rate of detachment of electrons from negative ions of atomic oxygen and (*ii*) the rate of heating and consequent decrease in density of the layer by the incidence of solar radiation. From the data it thus appears that the effect of heating at first predominates over that due to detachment of electrons. This effect persists for a longer time in summer than in winter.

## IV TRUE HEIGHT OF REGION F

For the purpose of determining true height from the observed virtual height, a method suggested by Murray and Hoag [5] has been adopted. A full description of the method is to be found in their paper. For calculation by this method it is not necessary to assume any particular type of ionization gradient of the layers. The method is, however, laborious, as, for each point of the curve showing the variation of true height with wave-frequency, it is necessary to carry out a long set of calculations. Recently, an elegant and more convenient method of calculation has been indicated by Booker and Seaton.[6] This method, however, assumes a parabolic gradient of ionization and yields reliable results only if the actual gradient conforms to this type of gradient.

In Figures 9 to 12 the results of a calculation of the true height from the observed $(P'-f)$ curves for the Regions E and F are shown. The continuous line curves A′ and A are the $(P'-f)$ curves for the Regions E and F respectively and the broken-line curve B gives the true height to which a radio wave of a particular frequency rises before suffering reflection. It will be seen from the figures that, on an average, the true height is less than the virtual height by about 100 km.

The difference between the two increases as the critical frequency is approached. It is to be noted also that the average difference varies from day to day. In Figs. 10 and 11, the average differences are about 80 km. on 6th October, 1937, and about 150 km. on 1st December, 1937, respectively.

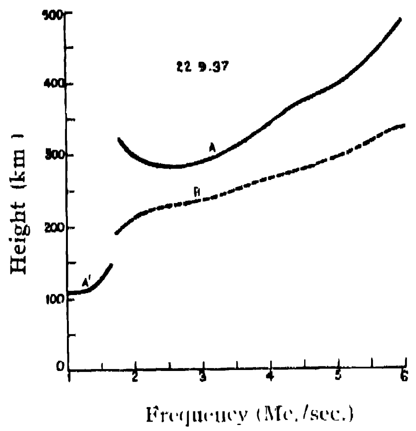
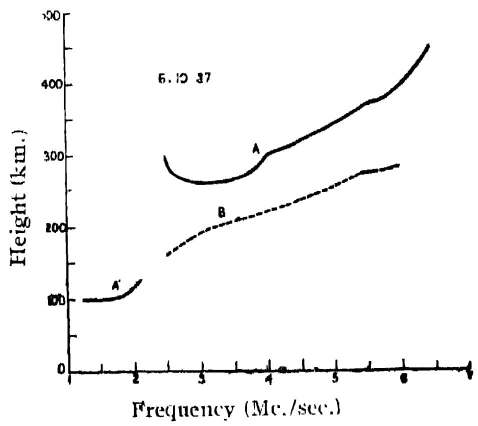



FIGURE 9

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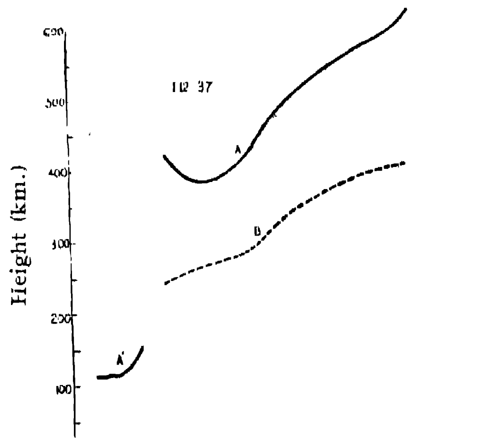


FIGURE 11

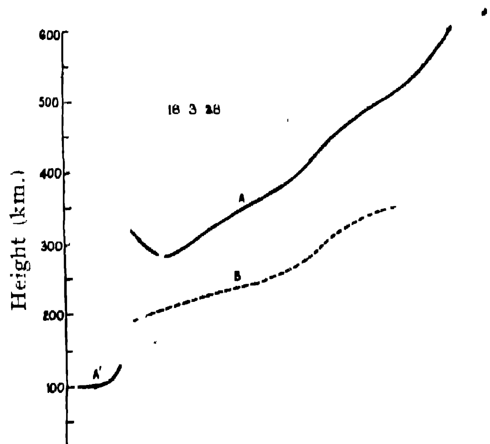


FIGURE 12

## V. HOURS OF SUNRISE AT DIFFERENT LEVELS OF THE ATMOSPHERE

The hours of sunrise in different seasons at various heights above the earth's surface have been calculated by using the well-known astronomical relation between the zenith distance of the sun, latitude of the place of observation and the hour angle of the sun for sunrise at any particular height. The effect of refraction which accelerates the time of sunrise has been taken into account. In Figs. 13 and 14 curves delineating the variation of the hour of sunrise for the latitude of Calcutta (22° 33′ N) with height are given. Since it is not practicable to give the curves for all days on which observations have been made, these are drawn here for a complete year at intervals of about a fortnight so that they may be used by the ionospheric investigators in this country.

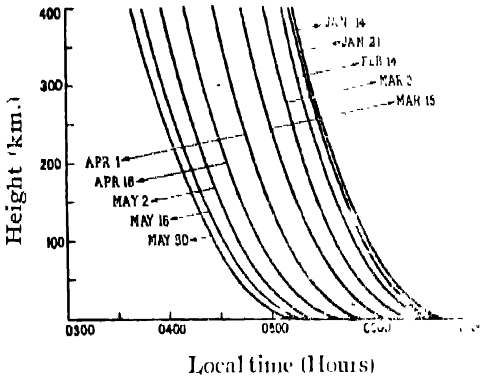


FIGURE 13

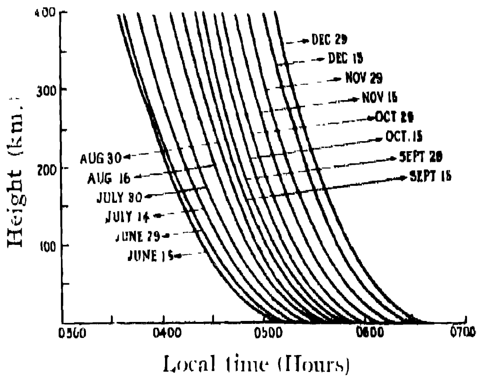


FIGURE 14

ACKNOWLEDGMENTS

The investigations described in this communication were undertaken at the suggestion of Prof. S. K. Mitra and I take this opportunity of recording my sincere thanks to Prof. Mitra for his advice and guidance in conducting the investigations.

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